08-16-00

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IN THE UNITED STATES
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PATENT APPLICATION

APPLICANT:	Helen H. Kim Meng-Lin Yu
CASE NAME:	Kim 6-8
TITLE:	Signal Detection Based on Channel Estimation

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Enclosed are the following papers relating to the above-named application for patent:

1. Transmittal Letter (1 page & 2 copies);
2. Declaration and Power of Attorney (5 pages);
3. Assignment Recordation Form Cover Sheet (orig. & 1 copy);
4. Assignment (3 pages);
5. Information Disclosure Statement with Form PTO-1449 (3 pages, with 2 references); and
6. Patent Application with Informal Drawings (1 Cover Page; 8 Pages of Specification; 3 Pages of Claims; 1 Page of Abstract; 3 Sheet(s) of Drawings).

CLAIMS AS FILED				
	NO. FILED	NO. EXTRA	RATE	CALCULATIONS
Total Claims	17 - 20=	0	x $18 =	$0
Independent Claims	2 - 3=	0	x $78 =	$0
Multiple Dependent Claim(s), if applicable			$240 =	$0
Basic Fee				$690
			TOTAL FEE:	$690

Please file the application and charge **Lucent Technologies Inc. Deposit Account No. 12-2325** the amount of $690.00, to cover the filing fee. Duplicate copies of this letter are enclosed. In the event of non-payment or improper payment of a required fee, the Commissioner is authorized to charge or to credit **Deposit Account No. 12-2325** as required to correct the error.

The Assistant Commissioner for Patents is hereby authorized to charge payment of any filing fees for presentation of extra claims under 37 CFR 1.16 and any patent application processing fees under 37 CFR 1.17 during the pendency of this application or credit any overpayment to **Deposit Account No. 12-2325**.

Please address all correspondence to **Steve Mendelsohn, Mendelsohn & Associates, P.C., 1515 Market Street, Suite 715, Philadelphia, Pennsylvania 19102**. Telephone calls should be made to me at Area Code (215) 557-6657.

Respectfully submitted,

Steve Mendelsohn

Date: 8/15/00

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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

SIGNAL DETECTION BASED ON CHANNEL ESTIMATION

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SIGNAL DETECTION BASED ON CHANNEL ESTIMATION

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to signal processing, and, in particular, to the processing of noisy received signals, such as high-speed optical signals distorted by linear and non-linear polarization mode dispersion (PMD) effects during transmission through an optical transmission path and resulting in data pulse broadening and inter-symbol interference (ISI).

Description of the Related Art

As transmission speed increases in optical fiber communications, polarization mode dispersion (PMD) becomes a significant factor limiting system performance, especially for transmission speeds of 10 Gb/s or higher. PMD causes data pulse broadening and creates inter-symbol interference (ISI). Unlike chromatic dispersion which can usually be countered by using a short dispersion-compensated fiber, PMD is time varying. While optical solutions have been proposed to counter PMD, they are usually very expensive and require a feedback path from the receiver back to the transmitter.

Traditionally, electronic adaptive equalizers have been used to mitigate received signal distortion resulting in ISI. Well-known techniques for channels having linear distortion include linear feedforward equalization and linear decision feedback equalization (DFE).

Fig. 1 shows a conventional equalizer **100** used to correct linear signal distortion. Equalizer **100** has two adaptive equalizers: adaptive equalizer **102** configured to provide feedforward equalization and adaptive equalizer **104** configured to provide decision feedback equalization. In particular, adaptive equalizer **102** receives the current received signal v_{in} and generates a linearly equalized signal v_{in}'. This equalized signal v_{in}' is presented to subtraction node **106**, which subtracts the feedback signal generated by adaptive equalizer **104**. The resulting difference signal is presented to slicer **108**, which decides whether the current received signal v_{in} corresponds to a "1" or a "0" by comparing the difference signal to a fixed threshold between 0 and 1 (e.g., half way between the reference voltages for logic "1" and logic "0" inside the slicer). The selected output data level is fed back to adaptive equalizer **104**. In addition, the error signal (i.e., the difference between the difference signal generated at subtraction node **106** and the sliced signal level generated by slicer **108**) is fed back to both adaptive equalizers **102** and **104** and used to dynamically control the coefficients within those equalizers using some conventional technique such as a least mean square (LMS) algorithm. Further information about typical implementations of adaptive equalizers **102** and **104** can be found in E.A. Lee and D.G. Messerschmitt, *Digital Communication*, Kluwer Academic Publisher, 1988, and S.U.H. Qureshi, "Adaptive Equalization,"

Proceedings of the IEEE, Vol. 73, No. 9, September 1985, the teachings of both of which are incorporated herein by reference.

When the channel is non-linear, such as an optical fiber channel dominated by PMD effects, non-linear equalization is used, since the effectiveness of equalizers, such as that shown in Fig. 1, is limited in those cases. Non-linear equalization techniques range from extremely complex solutions, such as those described in U.S. Patent No. 4,213,095, to simple single-tap non-linear DFE modules, such as those described in U.S. Patent No. 5,191,462.

In general, effective non-linear equalization is a very complex and difficult process, involving the inversion of the non-linear channel response such that the combined channel and non-linear equalizer frequency response is flat. The optimization cost functions are often not smooth convex functions and, as a result, considerable adaptation convergence difficulties exist. These difficulties are manifested by the complexity of the techniques described in U.S. Patent No. 4,213,095.

SUMMARY OF THE INVENTION

The present invention is directed to a receiver that relies on channel estimation to mitigate inter-symbol interference (ISI) problems, especially when the channel is non-linear. When channel non-linearity is predominantly quadratic, a channel estimation-based receiver of the present invention performs extremely well with much lower complexity than traditional non-linear equalization techniques. The adaptive electronic solution of the present invention provides a versatile and cost-effective technique for correcting polarization mode dispersion (PMD) problems in optical transmission systems. One possible application of the present invention is to mitigate fiber PMD in high-speed SONET systems, such as OC192, especially where second-order PMD, also known as polarization-induced chromatic dispersion (PCD), is strong.

In one embodiment, the present invention is a receiver for a received signal having two or more data levels, the received signal having been transmitted over a transmission channel, the receiver comprising (a) two or more channel estimators, at least one channel estimator for each different data level for the received signal, each channel estimator being configured to model the transmission channel to generate an estimated signal corresponding to one of the data levels; and (b) a comparator configured to (1) receive the received signal and the estimated signal from each channel estimator and (2) select an output data level for the received signal.

In another embodiment, the present invention is a method for processing a received signal having two or more data levels, the received signal having been transmitted over a transmission channel, the method comprising the steps of (a) generating at least one estimated signal for each data level based on a

model of the transmission channel; and (b) processing the received signal and the estimated signal for each data level to select an output data level for the received signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects, features, and advantages of the present invention will become more fully apparent from the following detailed description, the appended claims, and the accompanying drawings in which:

Fig. 1 shows a conventional equalizer used to correct linear signal distortion;

Fig. 2 shows a block diagram of a channel estimation-based receiver, according to one embodiment of the present invention, in which the received signal has two possible levels; and

Fig. 3 shows a block diagram corresponding to a shared-component implementation of the channel estimation-based receiver of Fig. 2.

DETAILED DESCRIPTION

Fig. 2 shows a channel estimation-based receiver **200**, according to one embodiment of the present invention. According to this embodiment, receiver **200** is designed to correct non-linear distortion for a received signal v_{in} having two different data levels corresponding to logic "1" and logic "0". Receiver **200** has two quadratic (i.e., 2[nd] order, non-linear) channel estimators: channel estimator **201** for level "1" and channel estimator **202** for level "0", where each channel estimator adaptively generates an estimate for one of the two data levels for the current received signal v_{in}.

The two estimated signals are present to a comparator comprising two subtraction nodes **215** and **216** and a compare-and-select module **217**. In particular, each estimated signal is subtracted from the current received signal v_{in} at one of the subtraction nodes and the two resulting difference signals are compared at compare-and-select module **217**, which decides whether the current received signal corresponds to a level "1" or a level "0" (e.g., based on which difference signal has the smallest absolute value).

Level "1" channel estimator **201** of receiver **200** comprises an adaptive equalizer **203** configured to receive a fixed reference signal v_1 corresponding to an ideal current level "1" signal. In addition, adaptive equalizer **203** receives feedback signals from compare-and-select module **217** corresponding to both the previous data output signal(s) as well as the previous error signal(s), where the error signal is used to dynamically control the coefficients within adaptive equalizer **203**, e.g., using a conventional LMS control technique. Adaptive equalizer **203** is preferably implemented based on conventional adaptive equalizer designs similar to that used for adaptive equalizer **104** of Fig. 1, since, in adaptive equalizer **203**, the tap data are sliced symbols.

Adaptive equalizers are typically implemented as finite impulse response (FIR) taps in hardware, which consists of multipliers, accumulators, and storage devices to implement equations like (a_k*coeff(1) + a_{k-1}*coeff(2) + ...), where a_k and a_{k-1} are current and previous inputs. For typical feedforward equalizers, where inputs represent either analog or digital input voltages, the required resolution is high. For feedback equalizers, inputs are sliced symbols (e.g., 0 or 1 in 2-level cases). Since only 1-bit resolution is needed, the multiplier design can be significantly simplified.

The output signal x_1 from adaptive equalizer **203** is processed in parallel through two processing paths within channel estimator **201**: a 1st order path and a 2nd order path. The 1st order path multiplies the output signal x_1 by a 1st order coefficient α_1 at multiplication node **207**, while the 2nd order path squares the output signal x_1 at squaring node **209** and multiplies the resulting squared signal x_1^2 by a 2nd order coefficient α_2 at multiplication node **211**. Channel estimator **201** also has a 0th order path, which multiplies a fixed reference signal v_{ref} by a 0th order coefficient α_0 at multiplication node **205**. The outputs from all three multiplication nodes are summed at summation node **213** to generate an estimated level "1" signal v_1^{est} corresponding to Equation (1) as follows:

$$v_1^{est} = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_1^2 \tag{1}$$

The estimated level "1" signal (v_1^{est}) is then subtracted from the current received signal v_{in} at subtraction node **215** to generate the difference signal for level "1" channel estimator **201** that is input to compare-and-select module **217**.

According to the present invention, each of multiplication nodes **205**, **207**, and **211** are dynamically controlled by the error signal generated by compare-and-select module **217** such that the coefficients α_0, α_1, and α_2 are all adaptive coefficients that are dynamically adjusted, e.g., using an LMS control technique. (Note that, in Fig. 2, the thick arrow is used to signify that the error signal is input to each of multiplication nodes **205**, **207**, and **211**.) In preferred implementations, the 1st order coefficient α_1 has a fixed value of 1. As such, the 1st order path can be implemented simply as a signal path connecting the output of adaptive equalizer **203** directly to the corresponding input of summation node **213** without requiring multiplication node **207**.

Level "0" channel estimator **202** is analogous to level "1" channel estimator **201**, with elements **204**, **206**, **208**, **210**, **212**, and **214** of level "0" channel estimator **202** configured to operate in analogous fashion to elements **203**, **205**, **207**, **209**, **211**, and **213** of level "1" channel estimator **201**, to generate the estimated level "0" signal, which is subtracted from the current received signal v_{in} at subtraction node **216** to generate the difference signal for level "0" channel estimator **202** that is input to compare-and-select module **217**. Note that the input to level "0" channel estimator **202** is a fixed, level "0" reference

signal v_0, which is different from the fixed, level "1" reference signal v_1. The resulting estimated level "0" signal generated by channel estimator **202** can be represented by

$$v_0^{est} = \beta_0 + \beta_1 x_0 + \beta_2 x_0^2 \tag{2}$$

where x_0 is the output signal from adaptive equalizer **204** and β_0, β_1, and β_2 are the adaptive 0^{th}, 1^{st}, and 2^{nd} order coefficients applied at multiplication nodes **206**, **208**, and **212**, respectively, and dynamically controlled based on the error signal generated by compare-and-select module **217**.

By including the 2^{nd} order terms ($\alpha_2 x_1^2$ and $\beta_2 x_0^2$), channel estimators **201** and **202** model a general 2^{nd} order system. If the transmission channel for received signal v_{in} is dominated by 1^{st} and 2^{nd} order effects, then channel estimators **201** and **202** should produce accurate replicas of the two possible channel outputs after they have been properly adapted to model the channel. The present invention avoids the typically difficult problem associated with conventional non-linear equalization schemes of having to invert the channel response.

Fig. 3 shows a block diagram corresponding to a preferred shared-component implementation of the channel estimation-based receiver **200** of Fig. 2. According to this shared-component implementation, receiver **300** is implemented with only a single adaptive equalizer **302**, which differs from adaptive equalizers **203** and **204** (e.g., the first tap corresponding to the current received signal is stripped). The output signal from adaptive equalizer **302** is used to generate the input signals for both channel estimators **201** and **202**.

In particular, the level "1" reference signal v_1 is multiplied by a coefficient c_1 (e.g., corresponding to the first tap of a conventional adaptive equalizer) at multiplication node **303** and the resulting product ($v_1 * c_1$) is added to the output signal from adaptive equalizer **302** at summation node **305** to generate the input signal to channel estimator **201**. Analogously, the level "0" reference signal v_0 is multiplied by the coefficient c_1 at multiplication node **304** and the resulting product ($v_0 * c_1$) is added to the output signal from adaptive equalizer **302** at summation node **306** to generate the input signal to channel estimator **202**.

Although the two channel estimators (e.g., **201** and **202** of Figs. 2 and 3) are shown with different sets of coefficients (α_0, α_1, α_2) and (β_0, β_1, β_2), in some implementations, the different channel estimators could be implemented using a single set of coefficients. In that case, the potential exists for even further sharing of components, where two or more channel estimators temporally share the same set of 0^{th}, 1^{st}, and 2^{nd} order path components, with different inputs being applied at different times corresponding to different channel estimators. Such temporal sharing would add latency to and decrease the speed (i.e., data throughput) of the receiver, which could make such an implementation unacceptable for certain

applications. Another way of sharing is to share the LMS update circuit for the coefficients and just copy the updated results for the two channel estimators.

Channel estimation-based receivers **200** and **300** may be implemented in software or in hardware, in either the digital domain or the analog domain, or in combinations thereof. For high-speed applications (i.e., data rates as high as 10 Gb/s or even higher), the receivers are preferably implemented in hardware in the analog domain.

Channel estimation-based receivers **200** and **300** are designed with the following characteristics:

- The received signal v_{in} has only two data levels ("1" and "0");
- The channel estimators contain only 0^{th}, 1^{st}, and 2^{nd} order terms; and
- Only the current and past data signals are fed into the adaptive equalizer(s).

Those skilled in the art will appreciate that the present invention can be implemented for applications having other characteristics.

For example, channel estimation-based receivers of the present invention can be implemented for applications in which the received signal has more than two data levels. In that case, the receiver is implemented with more than two channel estimators: (at least) one channel estimator for each different data level, where the estimated signal generated by each channel estimator is subtracted from the current received signal to generate a difference signal for the compare-and-select module, which still preferably selects the output data level for the current received signal based on the difference signal having the smallest absolute value.

Furthermore, channel estimation-based receivers of the present invention can be implemented for applications in which the channel estimators contain one or more additional, higher-order terms beyond the 2^{nd} order term. In that case, each channel estimator will have an additional processing path for each additional, higher-order term comprising, for example, a sequence of multiplication nodes to generate the higher-order term, where one of the multiplication nodes is an adaptive node corresponding to a dynamically controlled coefficient for the higher-order term.

Moreover, channel estimation-based receivers of the present invention can be implemented for applications in which each adaptive equalizer receives future data as well as the past and current data as tap inputs. In that case, the receiver should be implemented with a different channel estimator for each different combination of current and future data. For example, for a receiver designed for a received signal having two data levels "1" and "0" where the adaptive equalizers take into account the current data value and one future data value, the receiver will preferably have four different channel estimators: one for each different combination of possible current and future data values (i.e., 00, 01, 10, and 11). If the adaptive equalizers are configured to take into account two future data values, then the receiver will

preferably have eight different channel estimators corresponding to the eight different combinations of one current and two future data values.

These different characteristics can be combined such that, in general, a channel estimation-based receiver according to the present invention will preferably have m^{n+1} channel estimators: one channel estimator for each different possible combination of the current data value and n future data values, where each data value has m different possible levels, where m is an integer greater than 1 and n is a non-negative integer, and each channel estimator has p+1 processing paths corresponding to (0^{th}, 1^{st}, 2^{nd}, ..., p^{th}) order terms, where p is an integer greater than 1. In preferred shared-component implementations, different channel estimators will share adaptive equalizers. In one possible shared-component implementation, all m^{n+1} channel estimators will share a single adaptive equalizer with suitable components provided to generate the appropriate input signal for each different channel estimator from the single output signal generated by the shared adaptive equalizer.

Although the present invention has been described in the context of processing electrical signals corresponding to optical signals transmitted over optical fiber transmission channels, the present invention can also be applied to signals received from other types of transmission channels, including electrical or wireless (i.e., "over-the-air") transmission channels.

The present invention may be implemented as circuit-based processes, including possible implementation on a single integrated circuit. As would be apparent to one skilled in the art, various functions of circuit elements may also be implemented as processing steps in a software program. Such software may be employed in, for example, a digital signal processor, micro-controller, or general-purpose computer.

The present invention can be embodied in the form of methods and apparatuses for practicing those methods. The present invention can also be embodied in the form of program code embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, or any other machine-readable storage medium, wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the invention. The present invention can also be embodied in the form of program code, for example, whether stored in a storage medium, loaded into and/or executed by a machine, or transmitted over some transmission medium or carrier, such as over electrical wiring or cabling, through fiber optics, or via electromagnetic radiation, wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the invention. When implemented on a general-purpose processor, the program code segments combine with the processor to provide a unique device that operates analogously to specific logic circuits.

It will be further understood that various changes in the details, materials, and arrangements of the parts which have been described and illustrated in order to explain the nature of this invention may be made by those skilled in the art without departing from the scope of the invention as expressed in the following claims.

CLAIMS

What is claimed is:

1. A receiver for a received signal having two or more data levels, the received signal having been transmitted over a transmission channel, the receiver comprising:

(a) two or more channel estimators, at least one channel estimator for each different data level for the received signal, each channel estimator being configured to model the transmission channel to generate an estimated signal corresponding to one of the data levels; and

(b) a comparator configured to (1) receive the received signal and the estimated signal from each channel estimator and (2) select an output data level for the received signal.

2. The receiver of claim 1, wherein each channel estimator implements a 2^{nd} order or higher model of the transmission channel.

3. The receiver of claim 2, wherein the model is an adaptive model of the transmission channel that is dynamically controlled based on an error signal generated by the comparator.

4. The receiver of claim 2, wherein each channel estimator comprises a processing path for each order term in the model of the transmission channel.

5. The receiver of claim 4, wherein at least one of the processing paths in each channel estimator comprises a multiplication node having an adaptive coefficient that is dynamically controlled based on an error signal generated by the comparator.

6. The receiver of claim 5, wherein a processing path in each channel estimator corresponding to a 1^{st} order term of the model with a coefficient having a value of 1, wherein the 1^{st} order term processing path is implemented without a multiplication node.

7. The receiver of claim 1, wherein the two or more channel estimators comprise one or more adaptive equalizers, each adaptive equalizer configured to receive a current data level corresponding to one of the data levels and to generate an input signal for one or more of the channel estimators.

8. The receiver of claim 7, wherein at least one adaptive equalizer is shared by two or more of the channel estimators.

9. The receiver of claim 8, wherein all of the channel estimators share a single adaptive equalizer.

10. The receiver of claim 7, wherein each adaptive equalizer is further configured to receive one or more future data levels and the receiver comprises a channel estimator for each different combination of current and future data levels.

11. The receiver of claim 7, wherein tap data for each adaptive equalizer corresponds to sliced symbols corresponding to the two or more data levels.

12. The receiver of claim 1, wherein the comparator comprises:

(a) a subtraction node for each channel estimator configured to generate a difference signal between the received signal and the corresponding estimated signal; and

(b) a compare-and-select module configured to receive the difference signals from the subtraction nodes and to select the output data level for the received signal based on a difference signal having a smallest absolute value.

13. The receiver of claim 1, wherein:

the transmission channel is an optical transmission channel; and

the two or more channel estimators and the comparator are implemented in a single integrated circuit as analog circuitry.

14. A method for processing a received signal having two or more data levels, the received signal having been transmitted over a transmission channel, the method comprising the steps of:

(a) generating at least one estimated signal for each data level based on a model of the transmission channel; and

(b) processing the received signal and the estimated signal for each data level to select an output data level for the received signal.

15. The method of claim 14, wherein step (a) comprises the step of implementing a 2^{nd} order or higher model of the transmission channel.

16. The method of claim 15, wherein the model is an adaptive model of the transmission channel that is dynamically controlled based on an error signal generated during step (b).

17. The method of claim 14, further comprising the steps of:

(c) generating a difference signal between the received signal and the corresponding estimated signal; and

(d) selecting the output data level for the received signal based on a difference signal having a smallest absolute value.

SIGNAL DETECTION BASED ON CHANNEL ESTIMATION

ABSTRACT OF THE DISCLOSURE

A receiver for a received signal having two or more different data levels comprises two or more channel estimators, (at least) one channel estimator for each different data level, where each channel estimator preferably implements an adaptive 2nd order or higher model of the transmission channel over which the received signals was transmitted to generate an estimated signal for one of the different data levels. The receiver also has a comparator that compares the current received signal to the estimated signals generated by the different channel estimators to select an output data value for the current received signal. The adaptive model of the transmission channel has coefficients that are dynamically controlled based on an error signal generated by the comparator. Each channel estimator relies on an output signal generated by an adaptive equalizer. In preferred shared-component implementations, each adaptive equalizer is shared by two or more different channel estimators, and, in one possible preferred shared-component implementation, all of the different channel estimators share a single adaptive equalizer.

FIG. 1 (PRIOR ART)

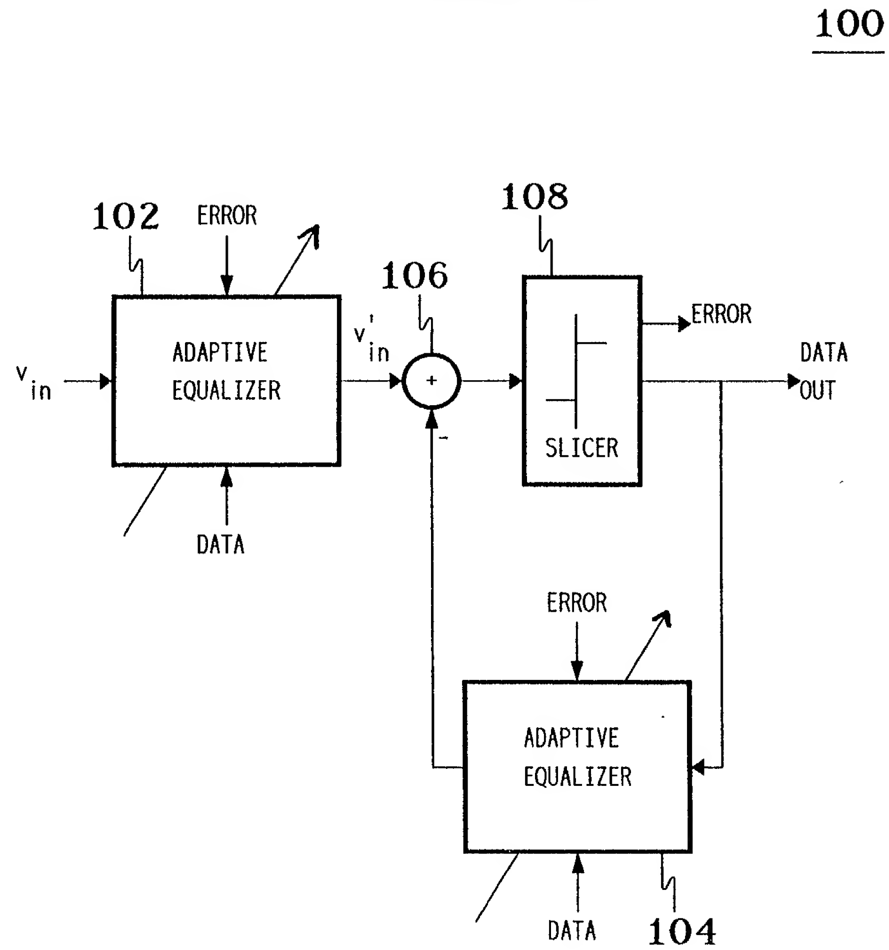
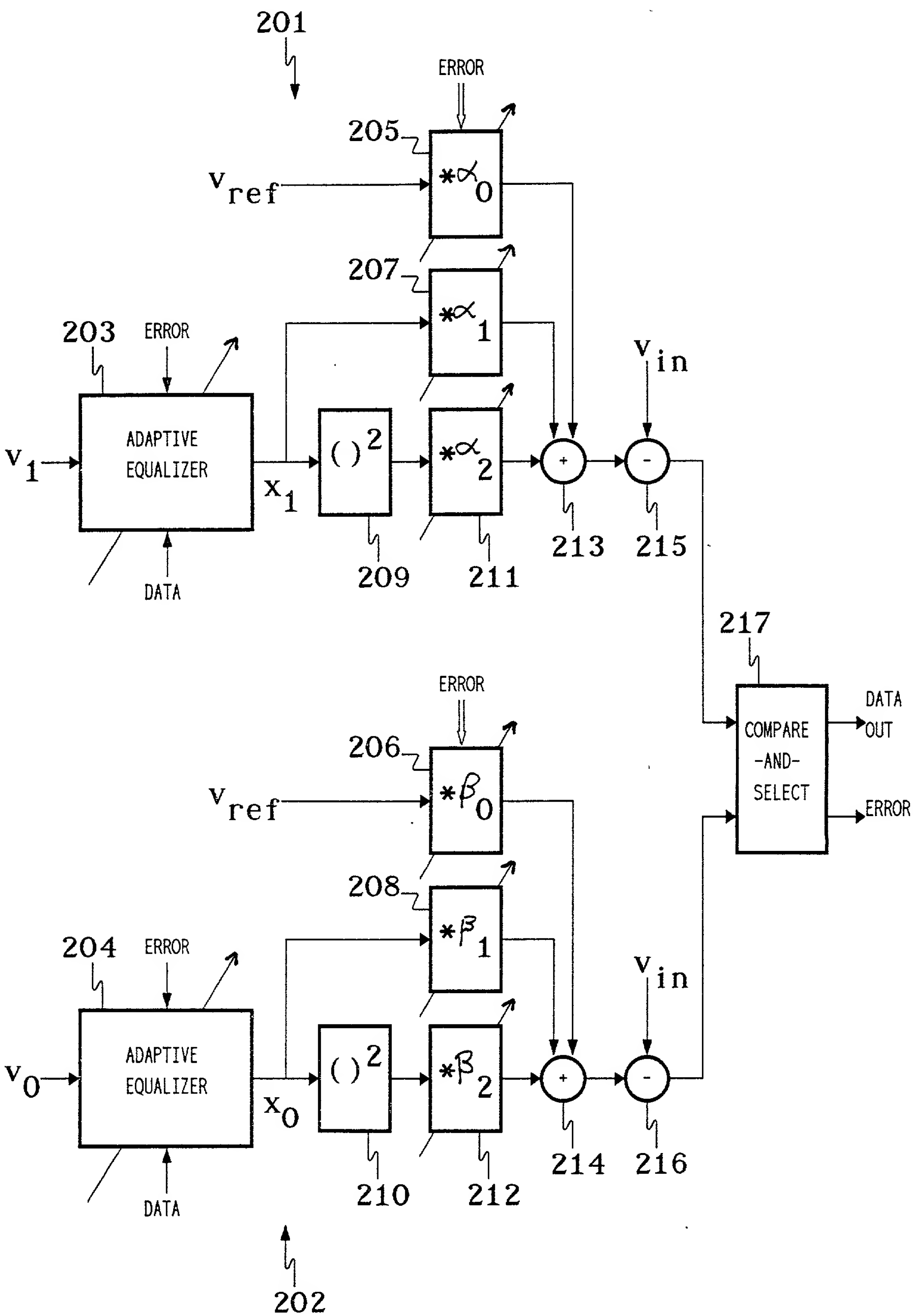


FIG. 2

200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205
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207
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203
ERROR
ADAPTIVE EQUALIZER
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DATA
$(\ )^2$
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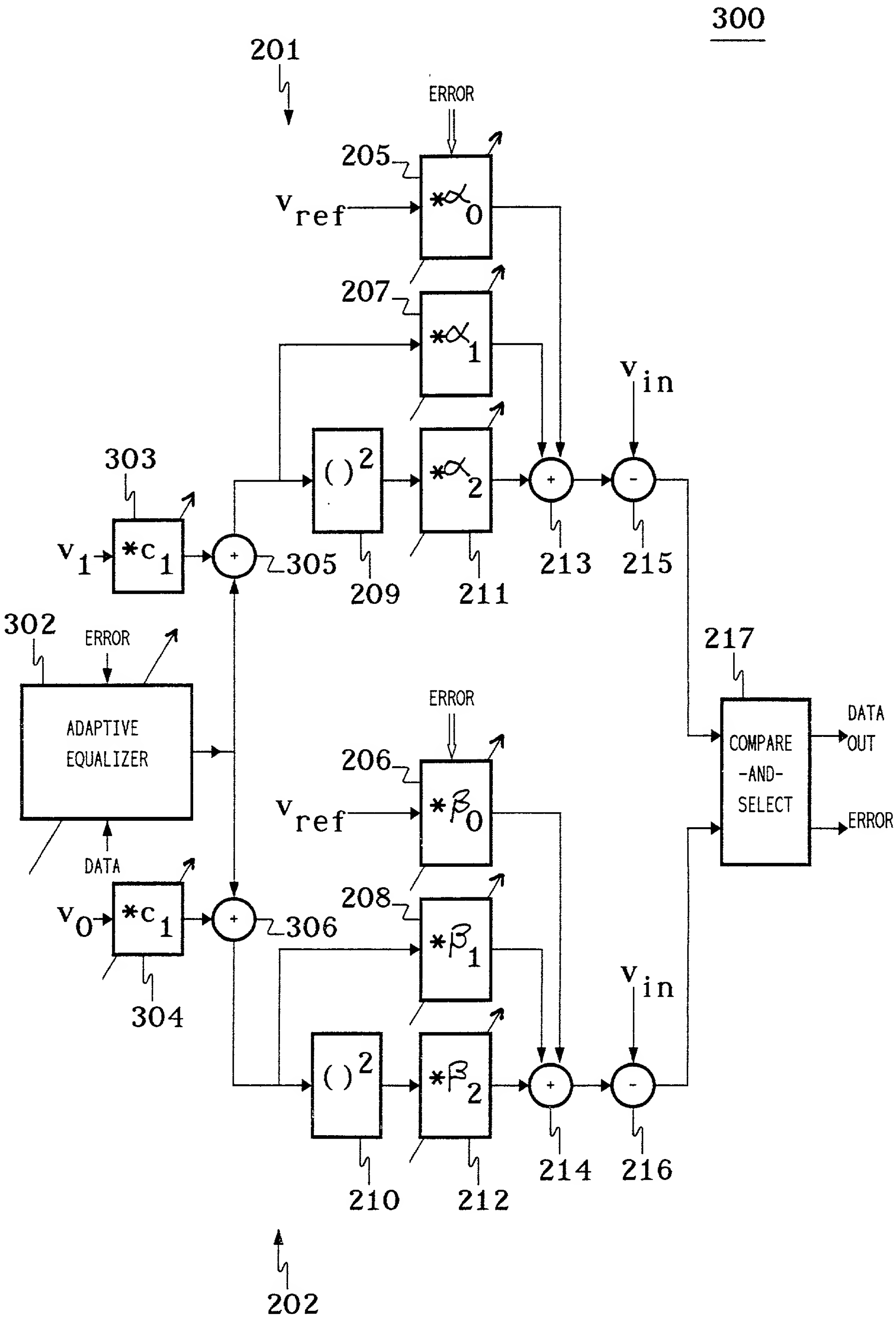
v_{in}
+
-
209
211
213
215
217
COMPARE -AND- SELECT
DATA OUT
ERROR
206
v_{ref}
$*\beta_0$
208
$*\beta_1$
204
ERROR
ADAPTIVE EQUALIZER
v_0
x_0
DATA
$(\ )^2$
$*\beta_2$
v_{in}
+
-
210
212
214
216
202

FIG. 3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201
202
ERROR
205
v_{ref}
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215
302
ERROR
217
ADAPTIVE
EQUALIZER
ERROR
206
v_{ref}
$*\beta_0$
COMPARE
-AND-
SELECT
DATA
OUT
ERROR
DATA
208
v_0
$*c_1$
306
$*\beta_1$
304
v_{in}
$()^2$
$*\beta_2$
210
212
214
216

Customer No.: 22186 Attorney Docket No.: Kim 6-8

IN THE UNITED STATES
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Declaration and Power of Attorney

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the first, original, and sole inventor (if only one name is listed below) or a first, original, and joint inventor (if multiple names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **Signal Detection Based on Channel Estimation**, the specification of which is being filed under the above-identified Attorney Docket Number.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 119(e) of any United States provisional application(s) identified below:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

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Michael B. Johannesen	(Reg. No. 35557)
Mark A. Kurisko	(Reg. No. 38944)
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I hereby appoint the attorney(s) on ATTACHMENT A as associate attorney(s) in the aforementioned application, with full power solely to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected with the prosecution of said application. No other powers are granted to such associate attorney(s) and such associate attorney(s) are specifically denied any power of substitution or revocation.

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ATTACHMENT A

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